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ABSTRACT

Sixteen kindergarten and 28 first-grade children were tested on two-choice discrimination problems. A prompt light indicated the positive (rewarded) object P on all training trials, and these were followed by a single nonprompted test trial during which a new object (X) replaced either P (X-N problems) or N (P-X problems) or neither (P-N control problems). Two additional control problems assessed verbal responses to the P and N objects alone. All Ss followed the prompt (i.e., displaced only P) and therefore never directly observed the nonreward value of N on prompted trials. However, performance was significantly above chance on nonprompted X-N trials. Control conditions and verbal reports permitted the conclusion that the negative (nonrewarded) value of N had been inferred while responding to P on prompted trials. Replicating previous findings, the present results further suggest that stimulus novelty is not an important factor in cue-substitution procedures. (Author)

Technical Report No. 74

INFERENCE IN DISCRIMINATION LEARNING OF EARLY ELEMENTARY SCHOOL CHILDREN

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Report from the Rule Learning Project
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STATEMENT OF FOCUS

The Wisconsin Research and Development Center for Cognitive Learning focuses on contributing to a better understanding of cognitive learning by children and youth and to the improvement of related educational practices. The strategy for research and development is comprehensive. It includes basic research to generate new knowledge about the conditions and processes of learning and about the processes of instruction, and the subsequent development of research-based instructional materials, many of which are designed for use by teachers and others for use by students. These materials are tested and refined in school settings. Throughout these operations behavioral scientists, curriculum experts, academic scholars, and school people interact, insuring that the results of Center activities are based soundly on knowledge of subject matter and cognitive learning and that they are applied to the improvement of educational practice.

This Technical Report is from the Rule Learning Project in Program 1. General objectives of the Program are to generate new knowledge about concept learning and cognitive skills, to synthesize existing knowledge, and to develop educational materials suggested by the prior activities. This project focused on rules or descriptions of logical operations used in solving simple problems, with the long-range goal of relating a taxonomy of general classes of rules and their use to similar analyses of other cognitive skills used in school learning.

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ABSTRACT

16 kindergarten and 28 first-grade children were tested on two-choice object discrimination problems. A prompt light indicated the positive (rewarded) object P on all training trials, and these were followed by a single nonprompted test trial during which a new object (X) replaced either P (X+N problems) or N (P+X problems) or neither (P+N control problems). Two additional control problems assessed verbal responses to the P and N objects alone. All Ss followed the prompt (i.e., displaced only P) and therefore never directly observed the nonreward value of N on prompted trials. However, performance was significantly above chance on nonprompted X+N trials. Control conditions and verbal reports permitted the conclusion that the negative (nonrewarded) value of N had been inferred while responding to P on prompted trials. Replicating previous findings, the present results further suggest that stimulus novelty is not an important factor in cue-substitution procedures.

I
INTRODUCTION

A previous study by Fletcher and Garske (1968) demonstrated that preschool and first-grade children were able to achieve a significant degree of inferential learning about a non-responded-to object on a two-choice object discrimination task. Essentially, prompted training trials preceded test trials on which either the positive (P) or negative (N) object was replaced by a new (X) object (conditions X+N and P+X). During prompted trials Ss followed the prompt (i.e., displaced only P) and therefore did not directly observe the nonreward value of N. Above-chance performance on X+N trials indicated that Ss had inferred the value of N while responding only to P. However, an approach to novel objects per se would also result in above-chance performance on X+N trials. To evaluate this possible novelty effect, the experimenters subtracted performance on P+X trials from that on control trials (P+N) during which no substitution took place. After reduction of performance on X+N trials by this difference (which could have been attributable to novelty), the performance level on X+N trials was still significantly above chance, consequently inferential avoidance learning was assumed.

The present study attempted to replicate the above results, as well as to provide a further control for stimulus novelty by evaluating responses to P and N objects alone, thus avoiding the problem of a possible novelty effect which might be inherent in the cue-substitution procedure. If performance on P-only trials is similar to that on P+X trials, and if the same is true of N-only and X+N, one might assume that the two tasks (P or N alone and paired with X) are equivalent, and that performance on X+N is not an artifact of novelty in the cue-substitution procedure.

II
METHOD

SUBJECTS

The Ss were 16 kindergarten (9 male, 7 female) and 28 first-grade (15 male, 13 female) public school students. All Ss were test-naive, having had no previous experience with Es, apparatus, procedures, or stimuli.

The Es were three males and one female, all of whom were familiar with the apparatus and procedures prior to the beginning of testing.

APPARATUS

The test apparatus consisted of an adjustable-height table on which a detachable stimulus display unit was mounted (see Fletcher & Orr, 1967). The E was screened from S's view by a partition-like structure which served as the basic framework of the display unit. At the top front of this structure was a fluorescent light which illuminated the stationary problem tray when it was visible to S. Below this was a one-way mirror which permitted E to observe S. Mounted beneath the mirror were two independently operated curved screens (each a one quarter lengthwise segment of a cylinder), the front (outer) one transparent and the rear (inner) one opaque, which rotated on a pivot below the midline of the structure. When both screens were in the forward (closed) position, the problem tray was accessible to E from the rear. With the opaque screen rotated back, S could view the tray, but could not touch the stimulus objects because the transparent screen remained closed; when the clear screen was opened, S could displace an object.

The white acrylic problem tray, which was 24" long by 9" wide by 2 1/2" high, had three foodwells spaced 5" apart on its top surface. Each well was centered on the midline and toward the front of three 4"-wide channels. The front surface of the tray was angled 45 degrees from the horizontal and contained two 1" jeweled amber prompt lights which were located directly in front of the two outer foodwells.

Stimulus objects were multidimensional "junk" (nonsense) objects which had been randomly constructed from variously colored and shaped pieces of wood approximately 4" by 4", on which nondescript bits of metal, leather, plastic and wood had been glued or nailed.

PROCEDURE

Pretraining and testing were given in one session approximately 25 minutes in length.

Trial 1

The S was acquainted with the apparatus and procedures, and was shown an object being baited. He was then allowed to displace both objects in order to verify that the reward was under only one of the two stimulus objects.

Trial 2

The opaque screen was withdrawn, and S was asked to "Look at both objects." The prompt light was then lit, its significance explained, and after a short interval (about 2 seconds) the clear screen was opened. The S displaced one object and again was allowed to confirm a correct response by displacing the N object, or to confirm an error by displacing P.

Trials 3-7

The same as the previous trial, except that when the prompt was lit S was told that he would no longer be permitted to displace both objects, therefore he should only "Pick the object that has the candy under it."

Trial 8 (P object only trial)

The P object was placed in the center channel, baited, the opaque screen withdrawn, and S was asked "Is this the object that the candy was under?" If S answered correctly ("Yes"),

E verbally reinforced the response. The transparent screen was then withdrawn, and S was permitted to displace the object and receive his reward. If S responded incorrectly ("No"), E informed him of his error and then allowed him to displace the object to confirm his error but did not allow him to take the reward. This P-only trial was repeated until S answered correctly.

Trial 9 (N object only trial)

The N object was placed in the center channel unbaited. E again asked, "Is this the object that had the candy under it?" If S responded correctly ("No"), E verbally reinforced the response, handed S a candy over the top of the apparatus, and then allowed S to confirm his verbal response. If S responded incorrectly ("Yes"), E told him of his error and permitted him to displace the object to confirm that it had no candy. This N-only trial was repeated until S had answered correctly.

TEST SESSION

Testing immediately followed pretraining. In all cases three prompted trials with both P and N objects preceded a single test trial There were five different types of test trials, one for each of the following problems.

P-only Problem

The same procedure as Trial 8 of pretraining, except that if S responded incorrectly ("No") he was not allowed to displace the object to confirm his error.

N-only Problem

The same procedure as Trial 9 of pretraining, except that if S responded correctly ("No") he was not permitted to displace the object to confirm the truth of his response.

P + N Problem

The same two objects (P and N) from prompted trials (see procedure below) were presented. S was allowed to displace one object, and retrieve the reward if he responded correctly to the P object.

P + X Problem

The N object was replaced with a randomly chosen new object (X). The S displaced one object and retrieved a reward if he correctly responded to P.

X + N Problem

The P object was replaced with a randomly chosen new object (X). S displaced one object and retrieved a reward if he correctly selected N.

Prompted Trials

For the P-only + N-only conditions a verbal response was required on the test trial. For the P+N, P+X and X+N conditions an instrumental response was required.

The procedure for the three prompted trials was the same for all problems. The E randomly selected two new stimulus objects, arbitrarily designating one as positive (P) and one as negative (N). The opaque screen was withdrawn, and S was requested to "Look at both objects." When S had visually sampled both objects the prompt light was lit, and after about two seconds the clear screen was opened. The S displaced one object, retrieved a reward if correct, and then both screens were closed. If an incorrect response (displacing N) occurred on a prompted trial, testing on that block of trials was immediately discontinued, the next block begun, and that block was repeated at the end of the session using new stimulus objects.

The total test session comprised 5 blocks of 5 problems each, with each problem consisting of three prompted trials followed by one unprompted trial. The order of the five problems within each block was randomized for each S independently. On each of the last five problems in the last block of problems S was asked why he had made his choice. Verbal and instrumental responses were recorded on previously prepared data sheets. Rewards ("candies") were sugar-coated cereals; noncorrection procedures were used on all trials, and rewarded position was randomized. Throughout the session E carried on light conversation with S, consisting mostly of positive and negative verbal reinforcements where appropriate, in order to maintain (S's) motivation. If S showed signs of fatigue or wandering attention, he was given a short break before testing continued.

III
RESULTS

Comparisons in all cases will be of the performance on the terminal fifth problem, with the first four problems regarded as practice trials. Table 1 contains the percentage of correct responses by grade and test conditions. The normal approximation to the binomial distribution with a correction for discontinuity was used for the subsequent analyses. Performance on the X+N condition was not significantly above chance for either grade considered separately (kindergarten: $z = 1.25$; $.10 < p < .11$; first grade: $z = 1.32$; $.09 < .10$)[1] but performance for both kindergarten and first grade

[1] All reported probability levels are one-tailed probabilities.

Table 1

Percent Correct Responses on Test Trial of Terminal Problem for All Test Conditions with Responses Tabulated for Kindergarten and First Grade Separately and Combined

	Response Mode	Type of Stimulus Object		Combined	
		+(P)	-(N)		
Kindergarten (N=16)	Verbal	(P-only) 81%	(N-only) 69%	75%	
	Instrumental	(P+X) 75%	(X+N) 69%	72%	(P-N) 56%
	Combined	78%	69%		
First Grade (N=28)	Verbal	(P-only) 96%	(N-only) 93%	95%	
	Instrumental	(P+X) 75%	(X+N) 64%	70%	(P+N) 75%
	Combined	86%	79%		
Kindergarten and First Grade (N=44)	Verbal	(P-only) 91%	(N-only) 84%	88%	
	Instrumental	(P+X) 75%	(X+N) 66%	70%	(P+N) 68%
	Combined	83%	75%		

combined was significantly above chance (z = 1.96; $p < .025$). Response to the P-X condition was significantly above chance for both kindergarten Ss (z = 1.75; $p < .05$) and first graders (z = 2.46; $p < .01$), as well as for both groups combined (z = 3.17; $p < .001$). On the P+N condition kindergarten Ss did not respond at a level significantly above chance (z = 0.250; $p < .40$), whereas the results for first graders (z = 2.46; $p < .01$) and for the two grades combined (z = 2.26; $.01 < p < .05$) did reach significance.

Verbal response to the positive (P) object alone was well above chance, whether kindergarten (z = 2.25; $.01 < p < .02$) and first grade (z = 4.73; $p < .001$) Ss were considered separately or together (z = 5.28; $p < .001$). A similar evaluation of response to the negative (N) object showed that kindergarten Ss did not respond at a level significantly above chance (z = 1.25; $.10 < p < .11$), but that first graders did (z = 4.38; $p < .001$). The two grades combined were also well above chance (z = 4.37; $p < .001$).

An examination of the overall results for all conditions across grades follows (see Figure 1).

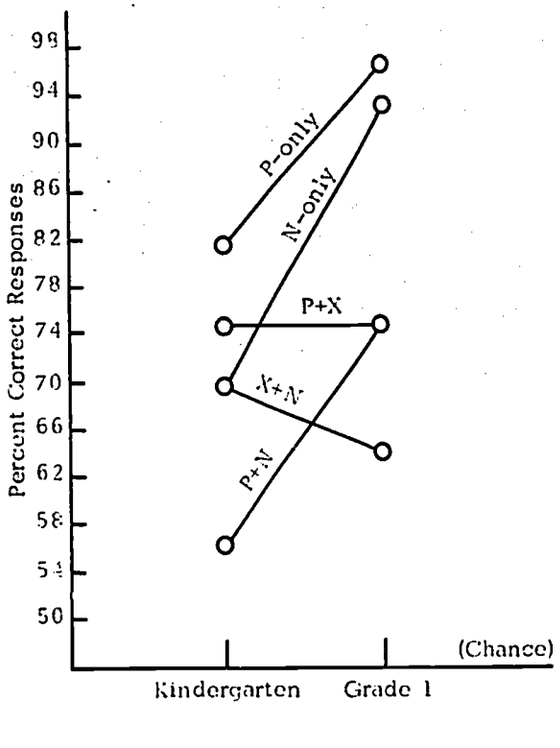

Figure 1. Percent correct responses by grade and test condition (test trial of terminal problem)

Such an examination revealed a general tendency for instrumental responses to be less accurate than verbal responses.[2] In addition, there was generally little difference across grades for instrumental tasks, with the exception of the very poor performance of kindergarten Ss on the P+N control condition. On the other hand, verbal response to both single stimulus objects (P and N) showed improvement across grades, with first graders performing better on both tasks. Verbal performance was generally above the level of performance on the three instrumental tasks for both grades. This was not true only in the case where kindergarten Ss performed at the same level on both the N-only and X+N tasks.

Within both grade levels, when verbal and instrumental modes of response are combined (see Table 1), performance is better on those tasks involving a previously positive stimulus object (P-only, P+X) than on those where a previously negative (N-only, X+N) object is present. In addition, first graders responded better on both types of tasks than did kindergarten Ss. When both grades are combined, the same relative superiority of performance holds for those tasks which retain a previously positive stimulus object.

As stated above, the primary comparisons of concern are of terminal problem performance. The difficulty with making such comparisons across grades for the various test conditions was that the performance of kindergarten Ss on the fifth problem for each condition seemed not to follow any consistent pattern in terms of what they had done on the first four problems. For example, terminal performance on the P+N problem was 56%, compared with an average of 73.5% for Problems 1–4. Conversely, P+X terminal performance was 69%, after an average of 43.5% for the previous four problems. Indeed, kindergarteners were quite variable across all problems compared with first graders (see Table 2). When the average percent of correct responses across all test conditions is calculated trial-by-trial (last column of Table 2), it may be seen that the within-condition variability of kindergarten Ss was such that

[2] It should be noted in speaking of "instrumental" versus "verbal" responses that mode of response is completely confounded with number of stimulus objects; i.e., one object occurred only in the verbal response condition, and two objects occurred only in the instrumental response condition. We therefore cannot be sure whether the differences which were found resulted from the nature of the response or from the type of stimulus situation.

Table 2

Percent Correct Responses Tabulated by Grade and Problem Number for Each Test Condition Separately and Combined

		Test Condition					
	Problem No.	P-only	N-only	P+N	P+X	X-N	All Conditions
Kindergarten	1	88	69	75	50	56	68
	2	75	69	69	75	56	69
	3	94	63	75	69	31	66
	4	88	81	75	63	31	68
	5	81	69	56	75	69	70
First Grade	1	75	61	54	68	54	62
	2	68	75	79	64	64	70
	3	71	71	61	68	54	64
	4	86	71	86	75	54	74
	5	96	93	75	75	64	80

there was essentially no improvement from Problem 1 to Problem 5 (68–70%, one reversal). First graders did show a fairly regular increase in performance (62–80%, one reversal), indicating an overall tendency to learn across the five problems.

Comparing across grades (see Table 3 below), one can see that first graders showed a greater proficiency in providing verbalizations of correct solutions than did kindergarteners for all conditions except P+N. Their superiority was most marked on the three conditions involving the greatest change from the prompted trials, i.e., P-only, N-only, and X-N. Both grades found the solution of the X+N condition the most difficult to verbalize. Only one S presented the unusual circumstance of coming to an incorrect solution while being able to explain the preceding reward contingencies correctly. In general, Ss were able to respond correctly with much greater frequency than they were able to provide an adequate verbalization of their solutions.

Table 3

Percentages of Subjects Making Adequate and Inadequate Explanations Following Correct or Incorrect Choices on the Terminal Trial

Grade	Verbalization	Choice	Test Condition				
			P	N	P+N	P+X	X+N
Kindergarten	Adequate	Correct	13	13	38	25	6
	Adequate	Incorrect	0	0	0	0	0
	Inadequate[a]	Correct	69	56	19	50	63
	Inadequate[a]	Incorrect	19	31	44	25	31
First Grade	Adequate	Correct	39	36	29	36	18
	Adequate	Incorrect	0	0	0	0	4
	Inadequate[a]	Correct	57	57	46	39	46
	Inadequate[a]	Incorrect	4	7	25	25	32
Kindergarten and First Grade	Adequate	Correct	30	27	32	32	14
	Adequate	Incorrect	0	0	0	0	2
	Inadequate[a]	Correct	61	57	36	43	52
	Inadequate[a]	Incorrect	9	16	32	25	32

[a]This category included cases where no explanation was provided.

IV
DISCUSSION

The present study attempted to replicate previous findings of inferential learning in young children (Fletcher & Garske, 1968), as well as to control for and evaluate the possible confounding effects of stimulus novelty which might result from the cue-substitution procedure. The possibility of a differential effect of task as a function of grade level was also investigated.

Inferential learning was demonstrated in the present study by the significantly better than chance performance of the total group of Ss on the X+X condition. The effect was not very strong, however, since the two grades separately did not perform significantly above chance. The significance of the combined performance was further qualified by the fact that the terminal problem performance of kindergarten Ss was not consistent with their performance on the first four problems and involved a sudden increase of 25%. Learning on the X+X problem was clearly the poorest of the five conditions; i.e., much less is learned inferentially about a nonrewarded, non-responded-to object than is learned from direct experience with a rewarded, responded-to object. It is possible that inferential learning may have been depressed by a factor unique to the X+X condition. If the nature of the prompting procedure had caused S to attend almost exclusively to the P object, despite instructions to "look at both," then he would tend to find both stimulus objects unfamiliar on the unprompted X+X trial. In such a case, X might then be responded to as the "more familiar" of the two, its previous reward contingency either having never been observed, or only vaguely perceived and then forgotten.

Ss in the present study performed at a level consistently below that demonstrated in the Fletcher and Garske study for the P+X, P+N, and X+X conditions. This performance differential may have resulted from several differences between the two studies. First graders in the previous study received one more problem for each test condition than either grade did in the present study. Preschoolers received the same number of problems per condition as Ss in the present study, but were given five prompted trials per problem. Moreover, although performance was evaluated for preschoolers on the first unprompted (test) trial, they received four more nonprompted test trials per problem, thus providing additional familiarity with the different test conditions and their reward contingencies. Had Ss in the present study received more prompted trials per problem and for more problems per test condition, their performance might have reached the level found in the previous study. In addition to having less "experience" with the P+X, P+N, and X+X conditions, Ss in the present study were tested on P-only and N-only, conditions which were not present in the other study. Having to deal with these additional types of problems may have placed an additional strain on the information-processing systems of these young children.

A further difference between the two studies which surely was effective in producing performance differences was the greater amount of pretraining given to Ss in the Fletcher and Garske study. Preschoolers were trained (to a criterion of 7 of 8 correct) on identical gray blocks to establish the cue value of the prompt. Then both they and first graders were given pretraining on unprompted two-choice object discrimination problems. Since all the pretraining in the present study involved prompted trials, we cannot be sure what S was responding to on test trials when the prompt light was off. It could be that, lacking any pretraining which would establish the continuance of the reward contingencies which obtained on prompted trials, Ss may have interpreted the absence of the prompt light as denoting a change in reward contingencies. This would be particularly likely if S were responding to the total stimulus complex.

Requiring Ss to state how they had gone about making their choices on the final problem for each test condition revealed that correct choices often were made without a corresponding ability to verbalize the conceptual basis for such responses. There is, of course, the problem of how the verbalization relates to actual performance. At the age level studied, it is not a safe assumption that there need be a direct or consistent relation between the two. Even the best verbalizations of the X+N problem solution were seldom obtained without some occassional "probing" suggesting that although the basis for solutions is present, it is not easily or spontaneously converted into an appropriate verbalization.

Performance on the terminal problem did not show any clear effect of grade (which might be expected) such as a uniform superiority of first grade on all tasks, or an interaction of problem type with grade level. This lack of consistent differences was apparently largely the result of the erratic performance of kindergarten Ss, who were extremely veriable within test conditions (problem types). Their performance on the terminal P+N problem represented an extreme drop (17.5%) from that obtained on the previous four problems to a point where their terminal P+N performance was 19% below that on the last P+X trial. At the same time, kindergarten X+N performance jumped 35% from the average of the first four problems so that they were actually performing 5% better than first graders, who had averaged 56% on Problems 1-4 and had never performed lower than 54% on any problem. These sudden fluctuations might conceivably be due to chance factors, since only sixteen (16) kindergarten Ss were tested. A trial-by-trial analysis of percent correct response by grade (collapsing across the five test conditions) revealed that, while first graders showed a relatively steady improvement over problems, kindergarteners evidenced no regular tendency to perform more correctly over the 5 problems

If the terminal problem performance of first graders is considered by itself, there is an ordering of proficiency across problem types: P-only>N-only>P+X = P+N>X+N. Single-object, verbal response tasks resulted in better performance than two-object, instrumental response tasks. Since mode of response and number of stimulus objects are completely confounded, little can be said about causality. Although within both modes tasks involving positive stimulus objects appear to result in better performance than those involving negative objects, this comparison is probably not very meaningful, since it will subsequently be shown that the N-only and X+N problems may not be equivalent, apart from considerations of mode of response and number of stimulus objects.

The P-only and N-only conditions were attempts to control for the possible effect of stimulus novelty which might result from the usual cue-substitution procedure employed in the P+X and X+N conditions. It was hoped that these conditions might provide a base level of response to the P and N objects against which any differences in performance on the P+X and X+N conditions resulting from the possible tendency to approach a new object could be evaluated. Unfortunately, they did not prove to be wholly unambiguous and successful controls. In addition to introducing the verbal response factor (which may be a problem in itself at the age level tested), it was theoretically possible for Ss to solve both problems without ever having attended to the N-object, i.e., without employing logical inference. For example, S could answer "No, that's not the one the candy was under" (referring to the N-object) merely by recognizing that it was not the positive, rewarded object which he had encoded, rather than by remembering that N was nonrewarded when paired with P. In addition, if "two objects" is a more complex stimulus situation than "one object," P-only and N-only are not equated with P+X and X+N on this basis.

As in the Fletcher and Garske study, subjects' comments and explanations once again provided no evidence for response to the novel object per se; e.g., Ss never said, "I picked that one because it was new." Moreover, the lack of difference between P+X and P+N performance is further evidence against a possible "stimulus novelty effect," which would predict (P+X)>(P+X). In general, then, the present study appears to reinforce the results of the previous one, in that children in the age range of 5-6 years demonstrate a statistically significant ability to learn inferentially about the reward value of the nonrewarded object while responding only to the rewarded object, and that such a tendency is not seriously affected by the presence of novel stimulus objects involved in the cue-substitution procedure. It therefore seems safe to conclude, as did Fletcher and Garske, that the three-task design (P+N, P+X, X+N) is an adequate method for assessing the occurrence of simple inferential learning.

It would seem desirable for future investigators to be certain that their subjects receive sufficient pretraining on both prompted and unprompted trials so that the cue value of the prompt, and the continuance of reward contingencies in its absence, are both well established

before actual test trials begin. In this way, the possibility of trial-and-error behavior (such as may have occurred with kindergarten Ss in the present study) in the absence of the prompt can be avoided. On the evidence of this and the previous study, it also appears that more than five problems per test condition will be necessary if strong evidence of inferential learning is to be obtained from subjects in the age range studied on discrimination tasks of the type employed.

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